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Simultaneous application of ultrasounds and firming agents to improve the quality properties of osmotic + freeze-dried foods

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ABSTRACT

Dried foods generally show poor rehydration ability and changes in the product properties. In this work, strawberries, used as a model food, were processed using osmotic dehydration (OD) followed by freeze drying (FD) to investigate the effects on the sample colour, texture, microstructure and rehydration. For the first time, a new approach was implemented by adding firming agents (FA) in the osmotic solution to strengthen the cell walls and applying ultrasounds (US) during the pre-treatment to enhance the process mass transfer. FA and US have been implemented often separately but never combined. The resulting samples were then further dried using FD. This strategy revealed to be successful in improving the properties of dried foods compared to FD solely: rehydration capacity was enhanced; colour was better retained, showing colour coefficients closer to the fresh fruit; texture was largely improved, exhibiting the same mechanical properties of the raw material; microstructure was well preserved.

1. Introduction

Drying is one of the main products processing in the food industry. It inhibits the microbial spoilage and the enzyme activity, thus extending the product shelf life (de Bruijn et al., 2016). Dried products are more convenient since their low volume allows reducing the packaging, transport and storage costs (Brown, Fryer Norton, Bakalis, & Bridson, 2008).

One of the key parameters that quantify the quality of a dried product is its rehydration capacity, i.e. the ability to reacquire the initial amount of water within its structure. Generally, dried products show moderate or low rehydration capacity, since cellular and structural ruptures occur during the drying process (Vega-Gálvez et al., 2015).

Among the drying techniques, freeze-drying (FD) gained interest since it provides both high water desorption and good retention of the food characteristics (Karam, Petit, Zimmer, Baudelaire Djantou, & Scher, 2016; Shishehgarha, Makhlouf, & Ratti, 2002). Long process times and high-energy demands, however, are required to obtain safe products, characterised by moisture content (MC) lower than 20–25 g/100 g and water activity (a_w) lower than 0.6. These conditions are generally regarded as the threshold values to avoid bacteria proliferation and enzymatic activity that can cause degradation of the product (Ratti, 2001; Stevenson et al., 2015; de Bruijn et al., 2016).

In order to overcome these limitations, some pre-treatments can be applied, for instance osmotic dehydration (OD). OD is a low-cost method, which allows more colour, aroma, nutritional constituents and flavour retention (Sagar & Suresh Kumar, 2010; Yadav & Singh, 2014). The application of osmotic dehydration allows an intermediate moisture product to be produced, which can be dried further using a conventional technique, with a reduced processing time (da Costa Ribeiro, Aguiar-Oliveira, & Maldonado, 2016; Prosapio & Norton, 2017; Ruiz-López, Huerta-Mora, Vivar-Vera, Martínez-Sánchez, & Herman-Lara, 2010). In a recent paper Prosapio and Norton (2017) investigated the influence of osmotic dehydration on freeze drying performance. They studied the effect of OD operating parameters (type of osmotic agent, temperature, concentration and processing time) and FD processing time on water activity, moisture content, solid gain, texture and rehydration. They showed that the application of the pre-treatment with Fructose 60 °Bx, at 50 °C and 180 min followed by 7-h freeze drying allowed to obtain the same samples' final water activity and moisture content of 18-h freeze drying alone. Nevertheless, they noted that, at the process conditions investigated, the rehydration capacity was lower than that obtained for freeze drying, as previously reported by (Ciurzyńska & Lenart, 2012; Seguí, Fito, & Fito, 2013). In their paper, Prosapio and Norton hypothesized that the cause of the lower rehydration capacity was related to the higher shrinkage that the samples experienced during osmotic dehydration.

Another common pre-treatment in food drying involves the use of ultrasounds (US). This technology has gained interest in recent years as

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Table 1
OD + FD experiments. Each value is expressed as mean ± standard deviation (n = 3).

#	Firming agent	C_{FA} [%w/w]	C_{OS} [°Bx]	a_w	MC [g/100 g]	RC %
1	–	–	40	0.439 ± 0.098^{a}	9.55 ± 0.75^{a}	24.88 ± 3.12^{a}
2			50	0.302 ± 0.074^{a,b}	8.98 ± 2.82^{a}	36.55 ± 1.02^{b}
3			60	0.195 ± 0.006^{b}	7.52 ± 0.79^{a}	30.00 ± 2.04^{a,b}
4	Calcium chloride	1	50	0.429 ± 0.018^{a}	13.56 ± 1.25^{a,b}	38.30 ± 3.93^{b}
5		5		0.471 ± 0.040^{a,c}	20.91 ± 1.08^{b}	30.06 ± 1.04^{a}
6		10		0.485 ± 0.011^{a,c}	31.31 ± 3.14^{c}	29.78 ± 1.27^{a}
7	Calcium lactate	1	50	0.429 ± 0.007^{a}	12.00 ± 2.38^{a}	40.84 ± 1.23^{b}
8		5		0.585 ± 0.064^{c}	17.89 ± 1.71^{b}	38.13 ± 1.35^{b}
9		10		0.597 ± 0.015^{c}	19.83 ± 4.38^{b}	31.09 ± 1.10^{a,b}

C_{FA}: concentration of firming agent; C_{OS}: concentration of osmotic solution; a_w: water activity; MC: moisture content; RC: rehydration capacity. The values followed by the same letter (abc) in the columns are not significantly different according to one-way ANOVA and Tukey's multiple comparison tests.

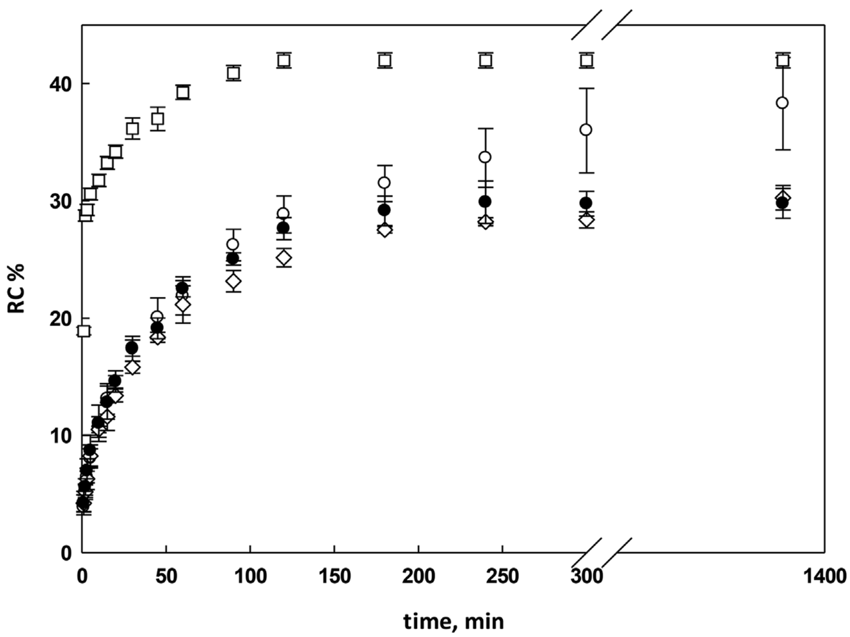

Fig. 1. Effect of the concentration of calcium chloride (runs #4-6): □ FD (data taken from (Prosapio & Norton, 2017)), ○ OD+FD calcium chloride 1% w/w, ● OD+FD calcium chloride 5% w/w, ◊ OD+FD calcium chloride 10% w/w.

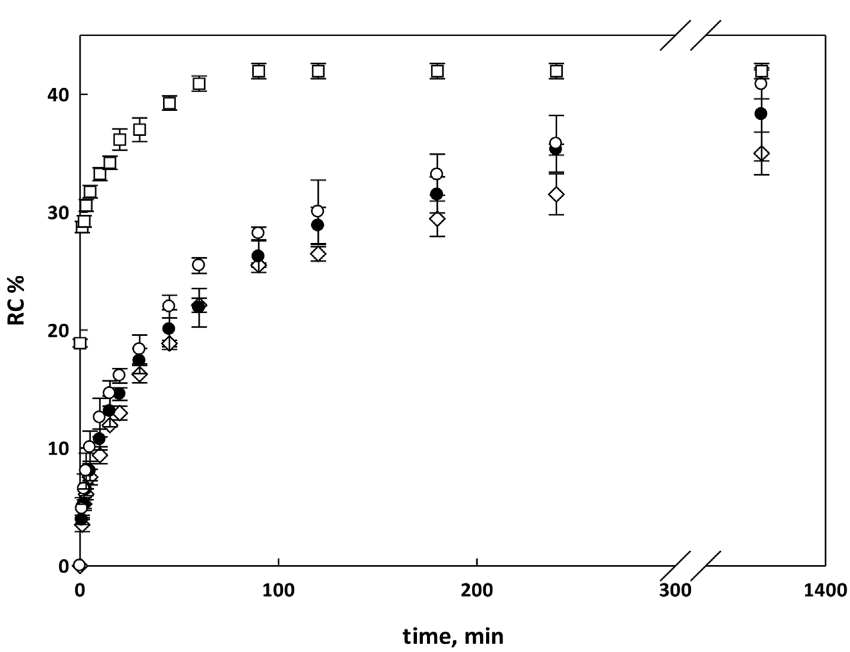

Fig. 2. Influence of the firming agent on the rehydration capacity of osmotic + freeze dried samples (runs #2, 4, 7 in Table 1): □ FD, ○ OD+FD 1% calcium lactate, ● OD+FD 1% calcium chloride, ◊ OD+FD.